RESEARCH DEPARTMENT

COLOUR TELEVISION:
THE ADAPTATION OF THE N.T.S.C. SYSTEM TO U.K. STANDARDS
PART 6: DISPLAY SYSTEMS

Report No. T-060/6

(1957/7)

W. Proctor Wilson

C.B.B. Wood

(W. Proctor Wilson)

COLOUR TELEVISION:
THE ADAPTATION OF THE N.T.S.C. SYSTEM TO U.K. STANDARDS

PART 6: DISPLAY SYSTEMS

March 1957

Report No. T-060/6

(1957/7)

COLOUR TELEVISION:

THE ADAPTATION OF THE N.T.S.C. SYSTEM TO U.K. STANDARDS

PART 6: DISPLAY SYSTEMS

SUMMARY

Three different methods of colour television display are discussed; these employ projection, three-tube direct-viewing and shadow-mask presentations. A description is given of some of the difficulties encountered in the design and construction of specimen displays of each type.

1. INTRODUCTION

The task of any colour television display is to produce three colour-separation images and cause them to be superimposed upon the retina of the viewer's eye, but the methods used to achieve this object differ considerably. A projection display of the three images, in register, upon a common screen might seem to be the most obvious approach, and many of the early monitors constructed in America were of this form; the limitations of projection television however soon led to higher quality display systems being produced, though at the expense of size and complexity.

Projection display systems nevertheless have the merit of simplicity and are relatively inexpensive; it was therefore decided to build one projection colour receiver to examine its potentialities and shortcomings.

At the other extreme, a large, three-tube direct-viewing laboratory monitor was constructed in order to appraise the effects of colour television systems when reproducing fine detail. This apparatus used three 17 in. (43 cm) rectangular cathode-ray tubes specially manufactured to very close tolerances. With such a monitor the three images are combined at the eye by means of semi-reflecting mirrors.

The third display method employs the shadow-mask tube which is virtually three cathode-ray tubes within the same envelope. The three images are displayed on interposed structures of phosphor dots, and become combined at the retina because the eye is unable to resolve the dot structures separately.

2. THE PROJECTION COLOUR RECEIVER

The intention underlying the construction of this apparatus was to gain an impression of the performance which might be obtained from a relatively cheap commercial colour receiver using only British components at present available. It was thought that in some cases the Mullard projection unit would be used by set manufacturers for the colour display, and three of these units were employed in the

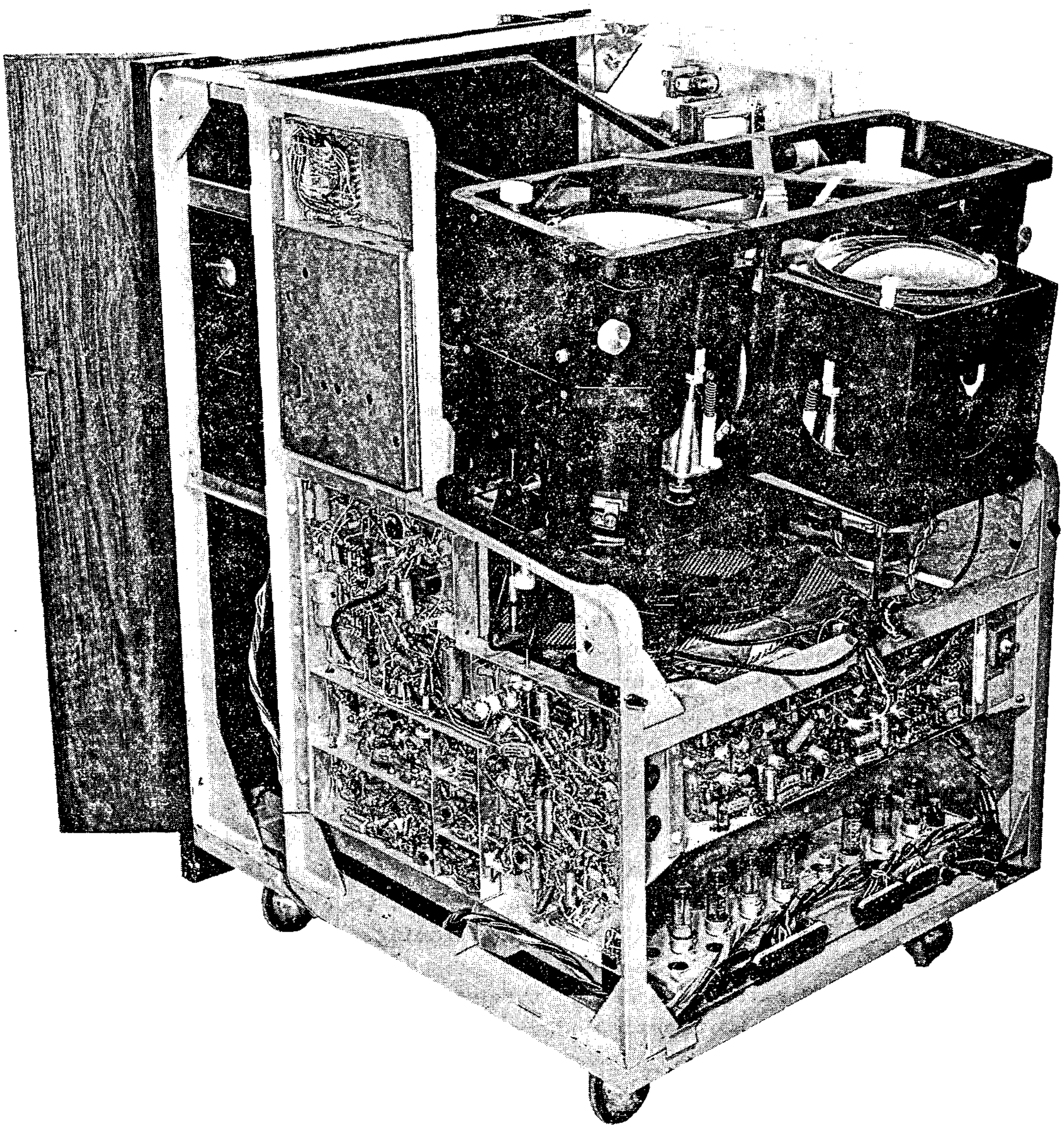

Fig. 1 - Projection Colour Receiver - rear view

receiver described. Many of the circuit arrangements in this receiver followed commercial practice rather than the more elaborate methods used for laboratory apparatus; for example, most of the valve heaters were series-connected, and the h.t. supply was obtained by half-wave rectification of the mains. Stabilisation of the supplies was confined to the e.h.t. (25 kV, 1 mA) which is derived from an r.f. oscillator circuit.

Fig. 1 shows a general view of the completed receiver and Fig. 2 is a diagram of the optical arrangements to permit superimposition of the three colour-separation images. Because of difficulties in obtaining dichroic mirrors at the time, the crossed mirrors were initially semi-reflecting, titanium dioxide films supported on 3 mm high quality glass plate; these mirrors reflect approximately 40% of the incident light and transmit the remainder, the absorption being negligible. It will be seen

that the optical efficiency of such a system is low, since the light from the blue and green projection units experiences one transmission through a mirror and also one reflection during its travel to the screen; the result is that only 24% of the light emitted is turned to useful account. The red projection unit was given preferential treatment by being placed in the rear position where the beam experiences no reflection, but is transmitted through both mirrors. Of the light emitted by this unit, 36% then reaches the screen; this arrangement partly compensates for the lower phosphor-efficiency of the red tube so that the beam currents are nearer equality when the display is reproducing a white.

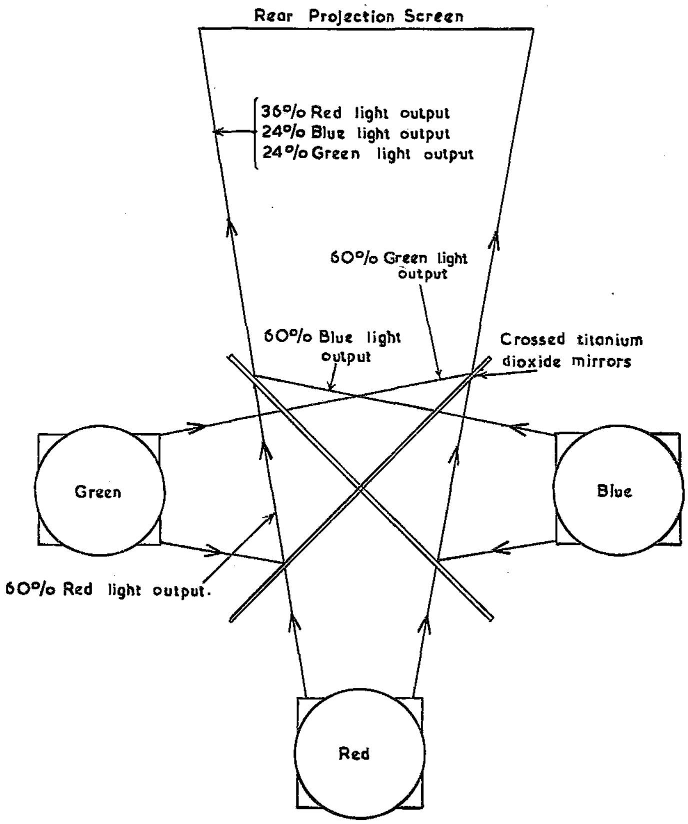

Fig. 2 - Projection Colour Receiver - Optical layout using titanium dioxide mirrors

In addition to low efficiency, there is a serious disadvantage when using this arrangement of titanium dioxide mirrors, which arises from the waste light causing desaturation of colours displayed. On further reference to Fig. 2 it will be seen that (neglecting divergence of the beam) 36% of the green light may enter the blue projection unit and vice versa, while 24% green and blue may enter the red projection unit. The remainder of the waste light is reflected back into the projection unit whence it came. Measurement shows that 18% of any light flux entering a Mullard projection unit by the corrector plate, through which the light normally emerges, is, after multiple reflection inside the unit, returned in the general direction of the source. This light is, of course, diffused, and a proportion of it finds its way to the screen via the mirrors while the remainder is again reflected around the system and so on.

Ideally, dichroic mirrors would overcome this difficulty since a mirror intended to reflect a certain colour would not transmit that colour at all; in practice, the advantage gained by their use is rather disappointing.

Practical dichroic mirrors do not wholly reflect or transmit light of a given wavelength, and up to 15% of the light incident is transmitted where it should be reflected and vice versa. As in the case of the achromatic titanium dioxide mirrors, this light can enter another projection unit and eventually give rise to a desaturating flare light in the manner already described.

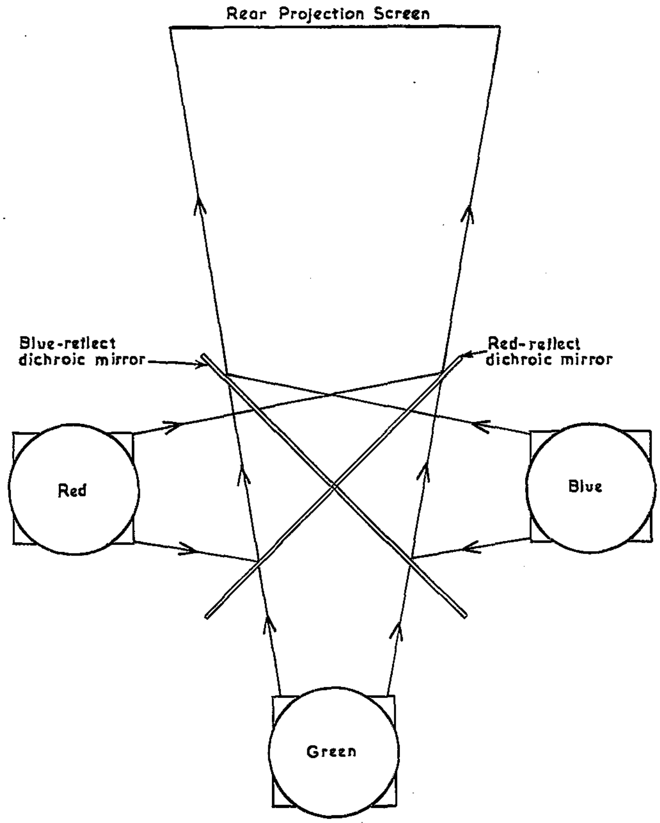

Fig. 3 - Projection Colour Receiver - optical layout using dichroic mirrors

In addition, the spectral emissions of the phosphors used to produce the three primary colours invariably contain low-energy contributions at wavelengths outside the pass-band of the dichroic mirror concerned, so that this light is incorrectly routed and a proportion becomes a flare light falling diffusely upon the screen.

These effects, when added to the inherently poor contrast of the projection unit (which is due to various halation effects and scatter at air-to-glass surfaces), combine to produce a low contrast, desaturated picture which compares unfavourably with some other methods of colour television display.

Some improvement could be made by adopting an optical layout which causes the waste light to be thrown clear of the system and be absorbed by some non-reflecting surface. Such a layout was used for the three-tube direct-viewing monitor described in Section 3, but this arrangement has much more bulk, and would be difficult to fit into the compass of a domestic television receiver cabinet.

When dichroic mirrors are used to combine the three light beams, as shown in Fig. 3, a colour "tilt" may be observed across the picture. This is due to the unfortunate property of dichroic mirrors that the wavelength of the point of crossover from reflection to transmission changes with the angle of incidence of the light. The light beam from each projection unit is non-parallel as it leaves the exit apertures of the units and therefore the angle of incidence at the dichroic mirror varies over the width of the beam. This results in the light destined for, say, the left-hand side of the picture having a different mean angle of incidence at the mirror from that which is destined for the right-hand side, and thereby a slightly different spectral distribution. This defect is not visible when titanium dioxide mirrors are used.

Adequate registration of the three colour-separation images does not present as much difficulty as might be expected. In the arrangement used, two of the three projection units were attached to the framework through cross-drive micrometer mountings so that the images could be brought into register by moving the unit bodily. These mountings were subsequently found to be unnecessary, since the slight tilt of a unit required to register the images introduced a negligible amount of keystone distortion.

2.1. Circuits

In designing the scanning circuits for a colour display which employs three separate tubes, the emphasis is always on producing three identical rasters rather than perfect geometry. It is in general desirable to drive the three pairs of line-deflecting coils in parallel, since stray capacities tend to cause the currents in the three coils to be unequal when they are connected in series. With the parallel connection, however, matching to the output stage presents a greater problem since the leakage inductance of the matching transformer becomes comparable with that of the load unless specially high-impedance deflector coils are available. In this particular receiver such coils were used, parallel connected, with small variable inductances connected in series with individual coils to permit pre-set balance of deflection sensitivities. The field deflector coils were also driven in parallel, each coil having a variable resistor in series for balancing. The scan generators were of orthodox design and need no description.

The only unusual feature of the circuit design was the successful use of a push-pull output stage in the video amplifier; the circuit employed is shown in Fig. 4. This arrangement was adopted because three normal video output stages would give rise to load fluctuations much beyond the capabilities of the simple, high source-impedance power supplies used.

2.2. Tube Protection

The limited screen brightness obtainable from a projection system inevitably leads to a very small safety margin in the operating conditions of the tubes. Furthermore the very high phosphor loadings call for special measures to prevent damage to the tubes by inadequate scanning drive or excessive beam current.

In the colour receiver, a high speed relay located in the time-base unit is connected in such a way that all three projection tubes are cut off unless both line and field scans are present at normal amplitudes. This prevents accidental damage during warm-up periods, but has unfortunately failed to operate quickly enough to protect the phosphor from burning in the event of a catastrophic scan failure. In order to achieve maximum highlight brightness it is usual to supply an orthodox black-and-white projection display from an e.h.t. generator with deliberately introduced poor regulation. Where the picture content gives rise to unusually heavy beam current (e.g. a large expanse of white sky) the e.h.t. falls substantially and the power dissipation of the phosphor is thereby limited. The scanning spot also becomes defocused. Where, however, only a small highlight area is included in the picture, the e.h.t. generator is able to supply the heavy current for short periods and it is then possible to permit peak beam currents considerably in excess of the highest average beam current which corresponds to a safe amount of heat generated in the phosphor. This procedure cannot be used in a three-tube colour display, since common e.h.t. supply does not give protection to individual tubes, and if three separate supplies were used the change of picture size with change of e.h.t. potential in any particular channel would give rise to misregistration in amounts dependent on picture content.

Since it is necessary that the e.h.t. supply should be common to the three tubes and stabilised to the order of ± 1%, full load/no load, damage to the tube may

result unless the video drive to the tube is in some way limited. To provide for the possibility of a plain, bright raster (i.e. "peak red", "peak green" or "peak blue") being required, the peak beam current in each tube must be limited to the maximum average value prescribed by the tube manufacturers, unless an arrangement more complicated than a simple limiter can be employed in the video drive. Such an arrangement would permit short peaks of high beam current to provide satisfactory highlight brightnesses, but in the presence of large bright areas it would vary the limiting level so that the safe average current was not exceeded.

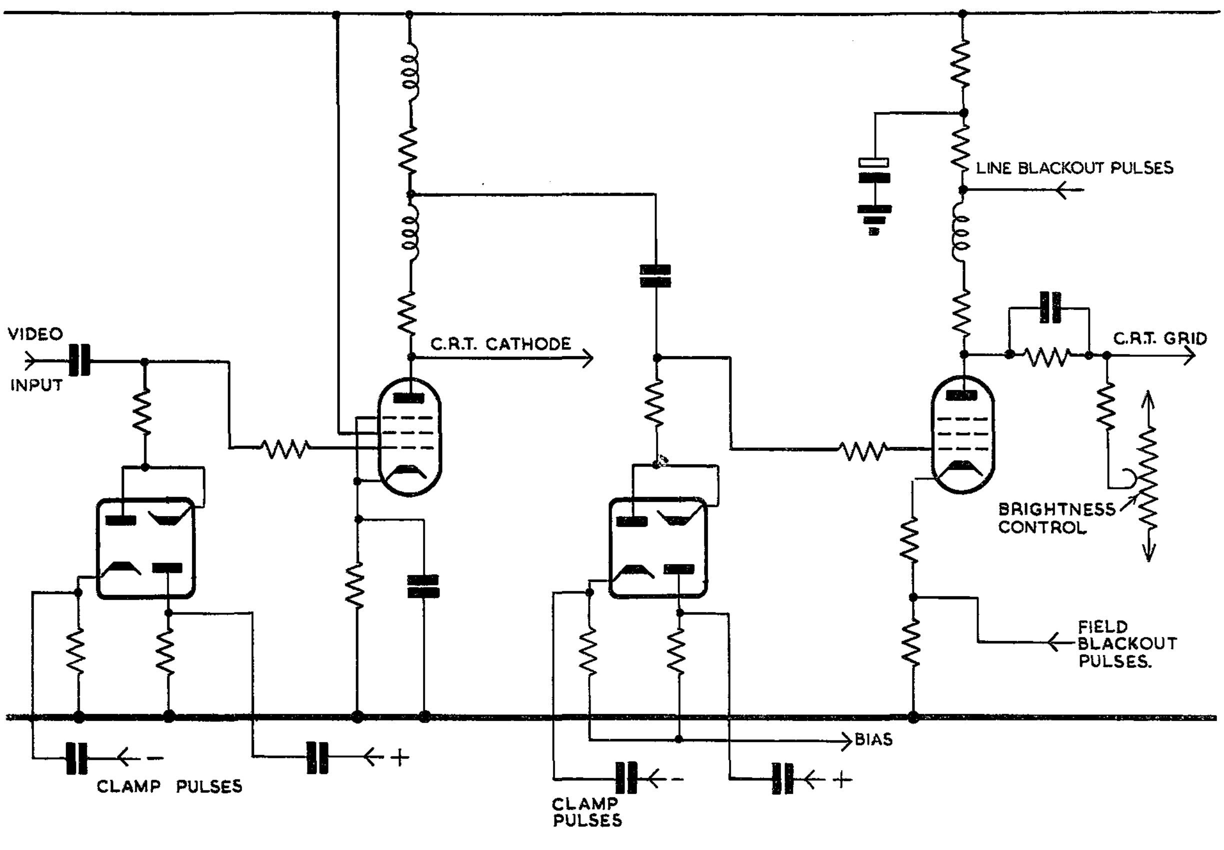

Fig. 4 - Push-pull video amplifier

In this simple receiver such a device was not considered justified and the video amplifiers and brightness controls were arranged so that the safe average current could not be substantially exceeded.

2.3. Performance

The performance of this receiver might fairly be summed up by saying that in the absence of any of the more elaborate displays for comparison, a non-technical viewer would probably find the presentation acceptable. To the engineer, the lack of contrast and the desaturation of colours is noticeable, and the restricted highlight brightness with imperfect resolution all combine to produce a picture which is generally "soft" and lacking in the qualities which the experienced viewer associates with good reproduction.

3. THE DIRECT-VIEW LABORATORY MONITOR

In contrast to the receiver just described, this monitor was constructed to give a display of the highest possible quality for the examination of minor colour defects in fine picture detail. It was felt that if the three colour-separation images could individually be made to have picture quality equal to that obtainable from the highest grade modern black-and-white monitor, the combination of the three would give a colour display whose technical shortcomings could be neglected when appraising a colour television system. The principal disadvantage of such a display is the large amount of space occupied compared with the picture area achieved. Fig. 5 shows diagrammatically the optical layout of the monitor and Fig. 6 shows the apparatus with the side covers removed. The cathode-ray tubes used were specially constructed with 17 in. (43 cm) rectangular, pressed-face envelopes containing high resolution electron guns. Special phosphors were used to give primary colours of the correct chromaticities and so render additional colour filtering unnecessary.

Combination of the three images is performed by two 17 in. x 12½ in. (43 cm x 32 cm) titanium dioxide films supported on 6 mm glass plates which were carefully selected for flatness. The reverse side of each plate is coated to avoid reflections.

Titanium dioxide mirrors are to be preferred for this application, since freedom from the colour tilts associated with dichroic mirrors is very important. The lower light efficiency of the titanium dioxide mirrors is not an embarrassment since with the outputs of three aluminium-backed direct-view tubes combined, adequate light is available. The tube layout is chosen to compensate partly for the differing phosphor efficiencies of the three tubes, and in the monitor described white light is produced when the beam currents are in the ratio R:G:B::125:165:105.

The principal difficulty in constructing such an apparatus is to achieve and maintain registration of the three images with sufficient accuracy to ensure that the high picture quality of the separation images is maintained in the combined display. This means that registration errors should not exceed, say, one picture element in the centre and two or three picture elements at the edges of the field.

The problem divides into two parts:

a. Mechanical and optical alignment of the three tubes to achieve registration of the three images at all practical viewing distances and angles, and

b. the production of three scanning rasters having identical geometry.

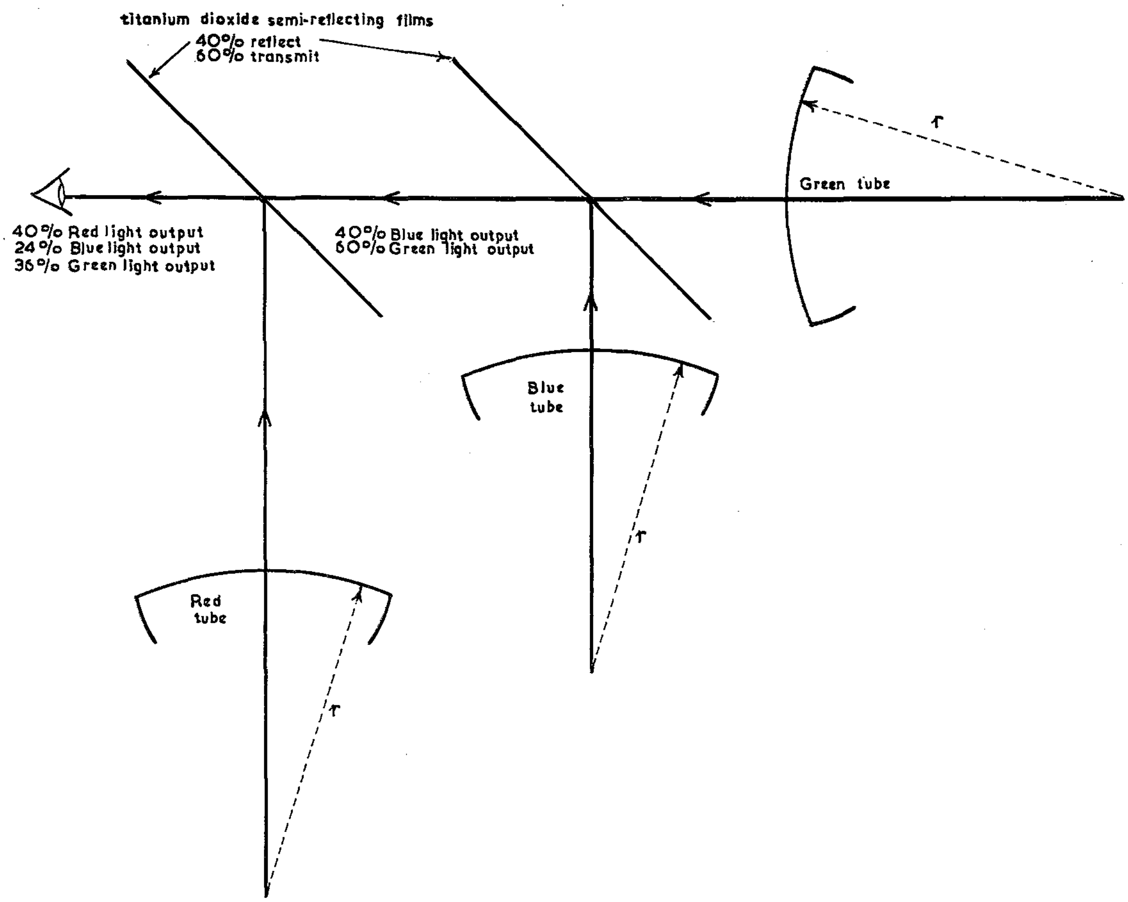

Fig. 5 - Optical combination of three direct-view images

It will be seen from Fig. 5 that there will be no parallax errors when the eye is optically equidistant from the poles of the spherical surfaces upon which the three phosphors are deposited. This would be true over the whole picture area and from all possible viewing angles provided the three spherical surfaces were of equal radius with their centres lying on the optical axes.

In making arrangements for the mechanical support of the three tubes, it was decided to fix permanently as many of the dimensions as possible. The tubes themselves were made to very close tolerances and therefore the supports were designed to ensure that the outer surfaces of the tube faces could be quickly and accurately located in positions pre-set with respect to the mirrors and to each other. This was achieved by casting light-alloy cradles into which the tubes were fitted before being placed in the monitor. Location of a tube within a cradle may be carried out by means of four rubber-faced blocks (with micrometer-screw drives) which bear upon the outer edges of the rectangular faceplate. Around the outside of the cradle is a machined spigot ring which locates into a companion casting bolted to the main framework.

During the manufacture of the cathode-ray tubes, a small cross is etched on the surface of the glass faceplate at the mechanical and electrical centres (which,

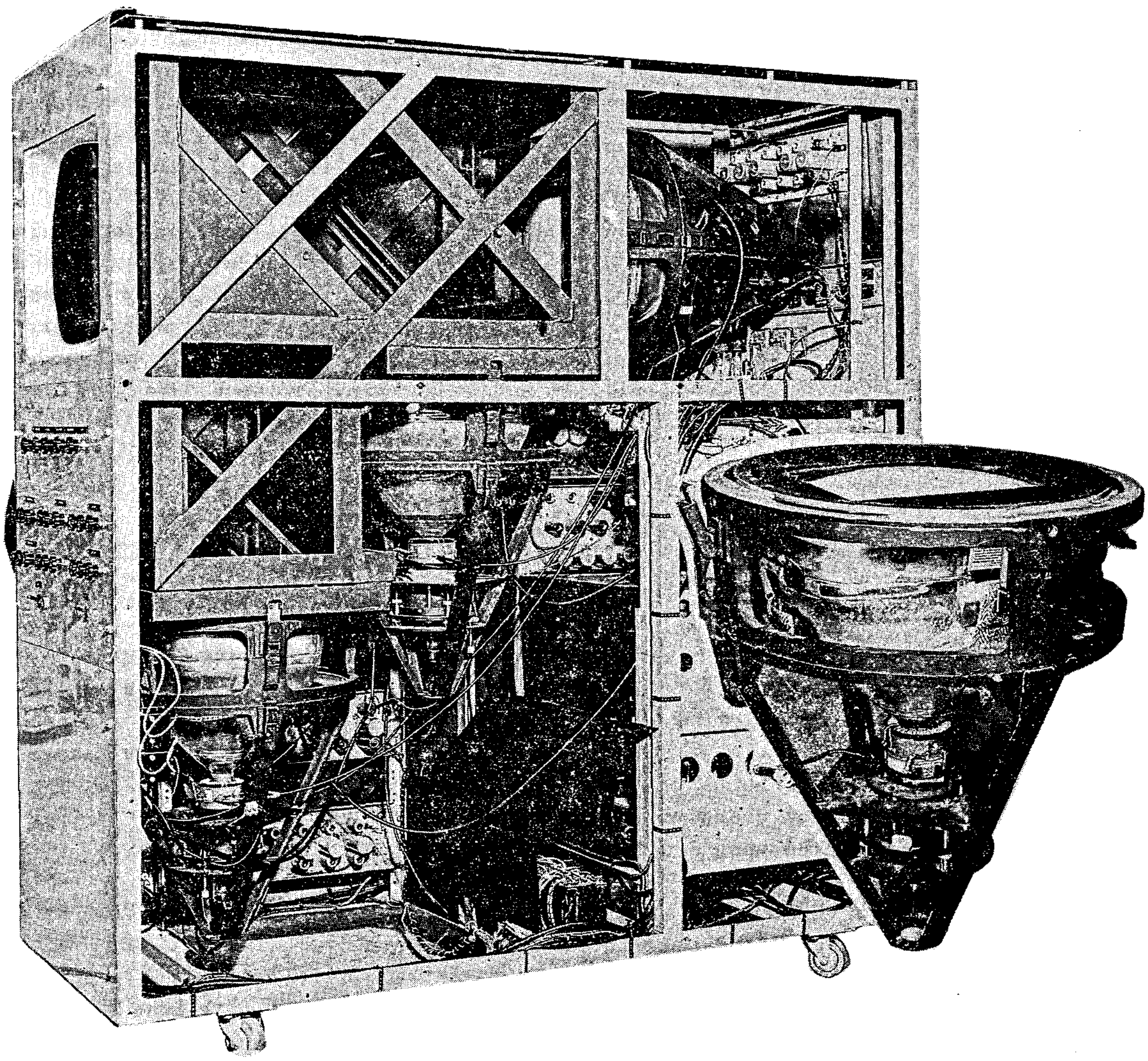

Fig. 6 - Three-tube direct-view colour television monitor

for this application, are of necessity coincident), and by using the micrometer-screw drives the tube is adjusted in the cradle until the etched cross lies at the centre of the machined locating ring around the outside of the cradle. A special jig permits this adjustment to be made simply and quickly. Once a tube has been centred in the cradle the assembly may be removed from the monitor and replaced as often as desired without further readjustment. The initial positioning of the cradle-locating castings was carried out by direct measurement and followed by optical checks with three identical engraved perspex disks which were placed in the positions to be occupied by the three tube faces. Once the correct positions had been determined, the necessary shims were inserted and the castings were fixed permanently to the stout angle-iron frame which serves to link the three tubes and two mirrors into a single unit. This entire assembly was then suspended within the monitor framework in such a way as to be unaffected by any flexing due to uneven floors.

The necessary presence of the glass plates upon which the semi-reflecting

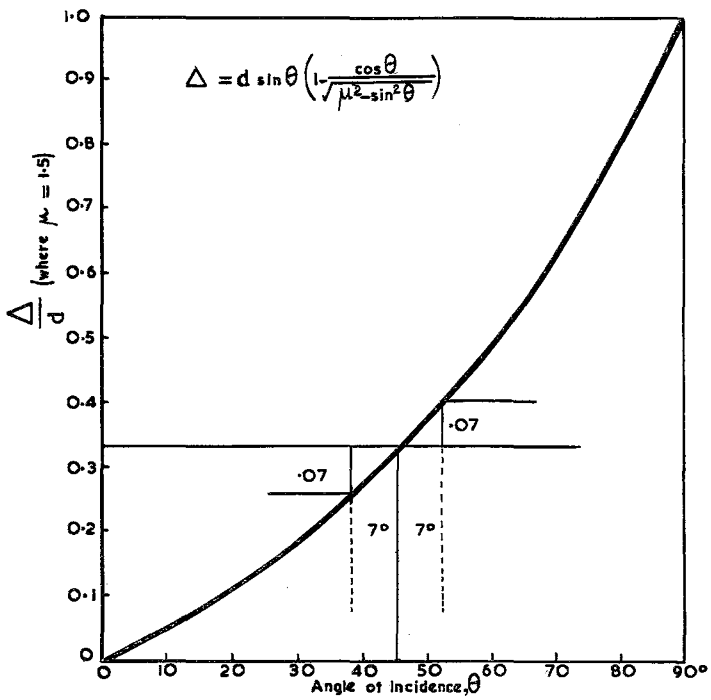

Fig. 7 - Image displacement as a function of angle of incidence

films are deposited gives rise to a complication which must be taken into account in determining the relative positions of the tubes and mirrors. Any light ray, after passing through one of the mirrors and its glass support, remains parallel to the incident ray but becomes displaced from it by an amount dependent on the thickness of the glass, its refractive index and the angle of incidence. The displacement is given by,

$$\Delta = d \sin\theta \left[1 - \frac{\cos\theta}{\sqrt{\mu^2 - \sin^2\theta}}\right]$$

where Δ = displacement
d = thickness of glass
θ = angle of incidence
μ = refractive index

The refractive index of the glass was taken to be 1·5 in plotting the curve of Fig. 7, which shows the relation between displacement and angle of incidence.

The angle of incidence, at a mirror, of the various rays travelling to the eye is, of course, not constant over the field and therefore different parts of the picture appear to be displaced by different amounts. In addition to a mean displacement of the whole image, there is a distortion of the relative positions of points within the image.

In the field direction the angle of incidence varies over the range 45° ± 7° and from Fig. 7 it will be seen that the mean displacement is 0·33 d while the maximum geometrical distortion resulting from the variation is approximately ± 0·07 d.

In the line direction, the mean angle of incidence is 0° so there is no displacement of the whole image but a symmetrical distortion of picture linearity exists. For the purpose of computing the distortion the effective thickness of the glass is $\sqrt{2}$ times the actual thickness, due to the 45° tilt.

With 6 mm plate glass supports, the non-linearities are only of the order of one picture element at the edges of the display and may therefore be neglected provided all three separation images are treated alike. The displacement of the whole image in the field direction could also be neglected if all three images were displaced by the same amount and in the same direction. It will be seen from Fig. 8, however, that while the rays from the green tube suffer displacement equal to 2Δ, those from the blue tube are displaced by only Δ, and those from the red tube are not displaced

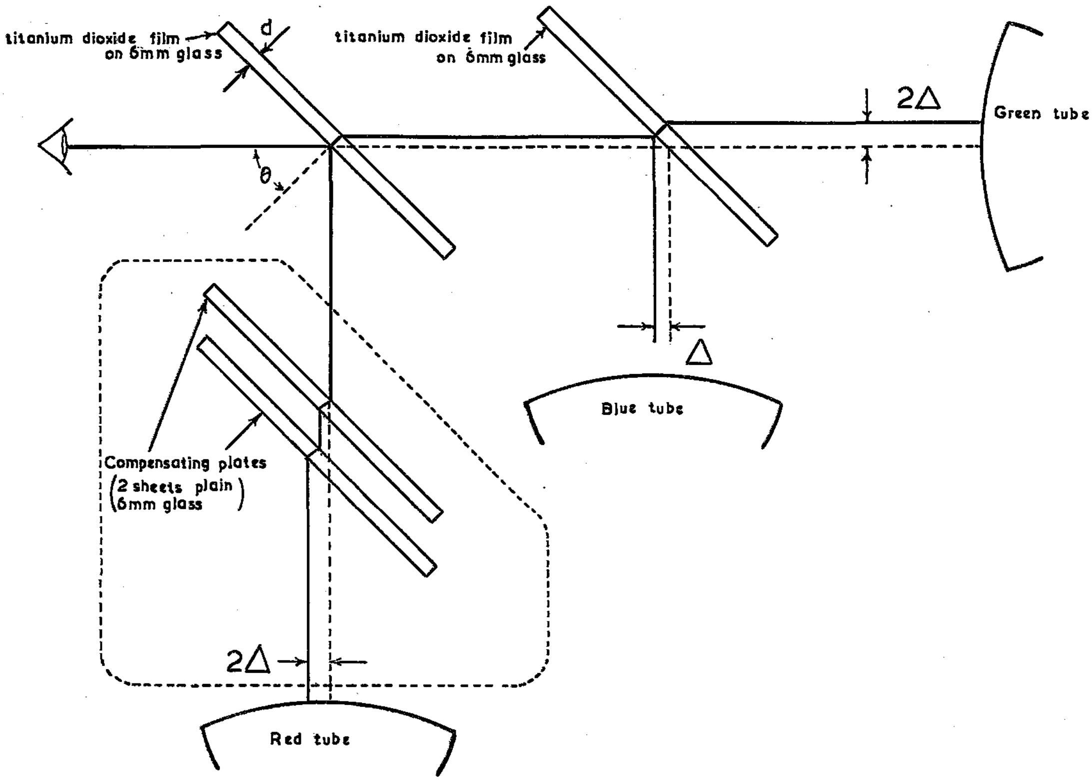

Fig. 8 - Three-tube direct-view monitor. Compensation for displacement of light rays

at all. The error in mean displacement could be corrected by moving two of the tubes by the requisite amounts with respect to the third, but this would bring the three images into perfect registration at only one point in the field direction; unequal displacements would still occur at other points and give rise to some degree of misregistration. Fig. 8 shows the method adopted to overcome this difficulty and, although the solution is not precise, the result is satisfactory. Two plain glass sheets are interposed between the mirror and the red tube, thereby introducing a displacement of 2Δ. Green and red are thus brought into complete coincidence, while the failure to obtain complete registration over the whole of the blue image (the tube having been displaced Δ in the correct direction) is not noticeable, since its luminance contribution to the complete picture is relatively low.

3.1. Tube Geometry

In seeking to produce three identical rasters of good geometry, special precautions were taken by the manufacturer (Cinema-Television Ltd.) of the tubes and the associated scanning and focus coils. The tube faces were selected for equality of radius (both internal and external) and freedom from ripples and other defects; a process which involved the examination of several hundred tube faces by means of a spherometer. The tube necks were precision-ground and accurately wound toroidal deflector coils were made a push-fit on to machined locating-sleeves cemented to the tube neck. During assembly of the tubes the gun structures were aligned so that the undeflected spot would centre upon the etched cross, already mentioned, which marks the centre of the tube face and the axis of the tube neck. The close mechanical

tolerances observed resulted in the tubes having deflection sensitivity, pin-cushion distortion, and deflection-defocusing characteristics sufficiently uniform to avoid obvious misregistration from these causes.

3.2. Circuits

The line scanning generator is of the orthodox energy-recovery type, efficiency being sacrificed to some extent in the interests of linearity. In order to provide for the introduction of d.c. shift into the line deflector coils, the output transformer has three separate secondary windings and the coils are therefore driven effectively in parallel. Each coil has in series a variable inductor and a 1 Ω variable resistor which permit fine balancing of scan amplitudes and linearity. The field deflector coils are also driven in parallel, in this case from a single secondary winding, and individual coils have a low value resistor in series for scan amplitude balancing.

In such a monitor, where size and economy are not important considerations, the use of fully stabilised power supplies is justifiable, and these were installed. Great care was necessary, however, to prevent 50 c/s magnetic fields from the power supplies causing minor deflection of the scanning beams. In an arrangement where the three tubes are widely separated, any hum field present will give rise to a disturbing periodic loss of registration which occurs at the difference frequency between the mains supply and the field scan.

The video amplifiers are of conventional design and the e.h.t. is provided by an r.f. oscillator circuit capable of producing 14 kV with 1% regulation (0 – 1 mA load).

3.3. Performance

The performance of this monitor has been found to be satisfactory. The picture quality of the separation images is comparable with that of good quality monochrome monitors and, by careful adjustment of scans and shift current, registration errors can be made undetectable except at extreme edges of the field. A satisfactory highlight brightness (say 20 ft lamberts) can be obtained without appreciable increase of spot size, and since the mechanical arrangement of the tubes shields them from ambient light and minimises flare troubles, the contrast range and saturation of the display are also very pleasing.

The principal disadvantages of such a monitor are:

Large bulk and expensive construction.
Expensive cathode-ray tubes.
Restricted number of observers (not more than three people can view at once with any degree of comfort).

4. THE 21 in. (53 cm) SHADOW-MASK TUBE MONITOR

The monitor illustrated in Fig. 9 employs the 21 in. R.C.A. Tricolor Kinescope, Type 21/AXP/22A, and was constructed in order to examine the performance which might be obtained from a display of this type. The tube is widely used in the United States of America and considerable information on circuits suitable for its operation is available in published form, but in this application the emphasis was placed on the best possible performance and therefore the circuits generally are more elaborate than those which have been described for use in commercially-produced receivers. Experience in operating the earlier 15 in. R.C.A. Tricolor Kinescope had led to the belief that the picture quality to be obtained from a shadow-mask tube is to a large extent a function of the performance of the circuits used to control it, and that the feature most in need of improvement was the short-term stability of these circuits. Accordingly in the 21 in. monitor care has been taken in the design of the circuits to ensure that all waveforms and voltages are precisely generated and, after an initial warming-up period, remain as constant as possible.

The design of the shadow-mask Tricolor Kinescope is fundamentally inefficient in beam current utilisation, since about 85% of all beam current is collected by the shadow mask and fails to reach the phosphor dots. This leads to the requirement for an e.h.t. supply of 25 kV capable of a mean current of not less than 800 μA with peaks up to 2½ mA.

The high final anode potential of this tube (coupled with the fact that the tube neck is 50 mm in diameter to accommodate the three guns) creates a demand for unusually high scanning currents. In addition, no less than twelve dynamic convergence waveforms have to be produced and combined into three groups to ensure that the three beams remain converged at all points in the scanning raster. It is, therefore, worth noting that while the 21 in. shadow-mask tube is a remarkably compact device for colour display, it requires additional and complicated circuits, accurately aligned, to produce good picture quality.

Brief descriptions of the types of circuit employed in the monitor are given below.

4.1. Time Base Synchronising Circuits

The monitor was intended primarily for laboratory use under conditions where the synchronising pulses would be free from noise and other interference, but provision was also made for alternative inputs, including modulated v.h.f. signals.

For checking transmission quality, the accurately positioned picture which results from the use of direct synchronising pulse triggering is to be preferred, but a flywheel type line scan synchronising circuit is included in the monitor and can be selected when experimental conditions (i.e., low v.h.f. field strengths) make its use desirable. The design of this circuit is fairly orthodox, employing a sine-wave oscillator with a phase discriminator and a reactance valve to control the oscillator frequency.

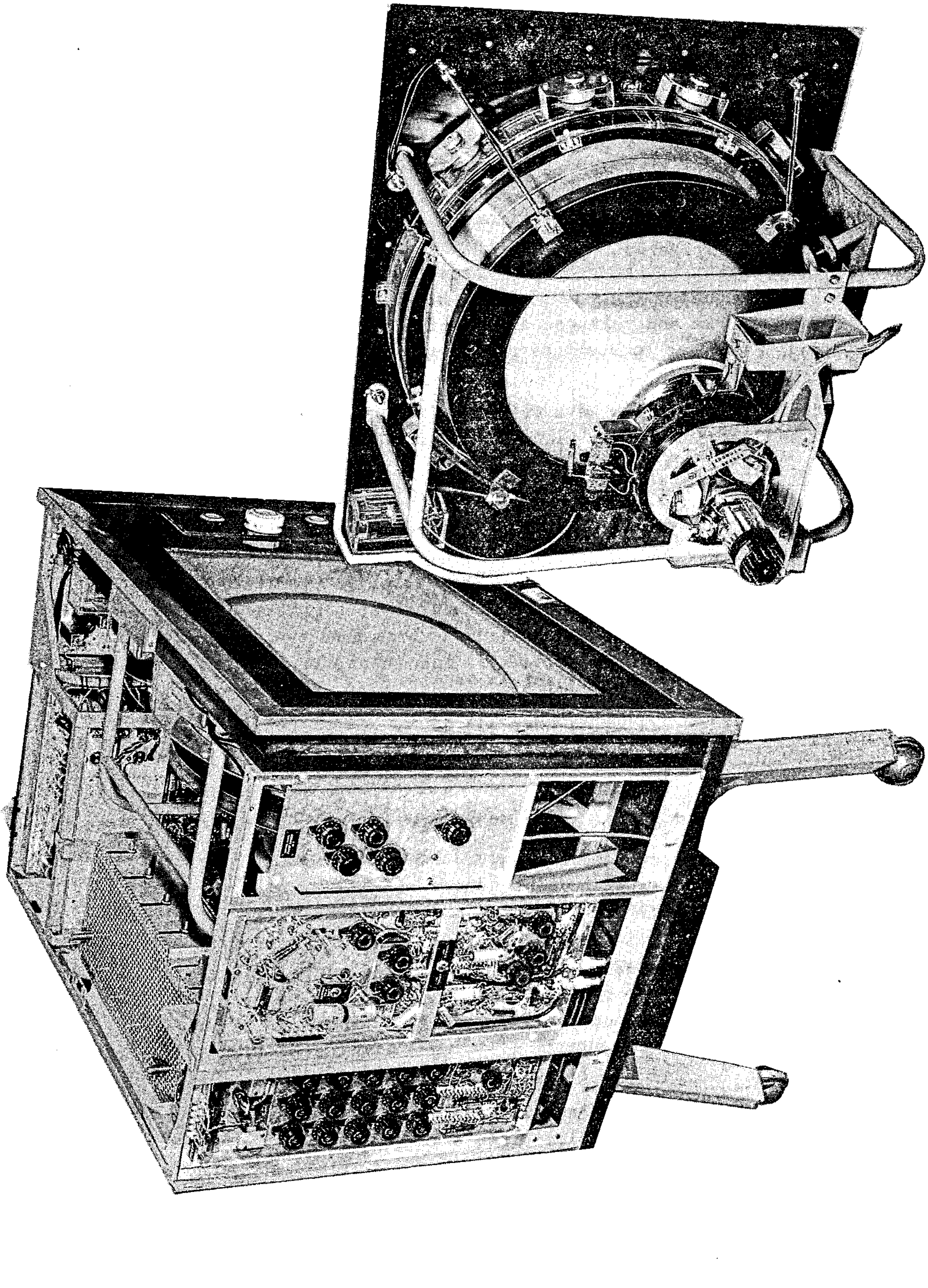

Fig. 9 - 21 in. shadow-mask tube monitor

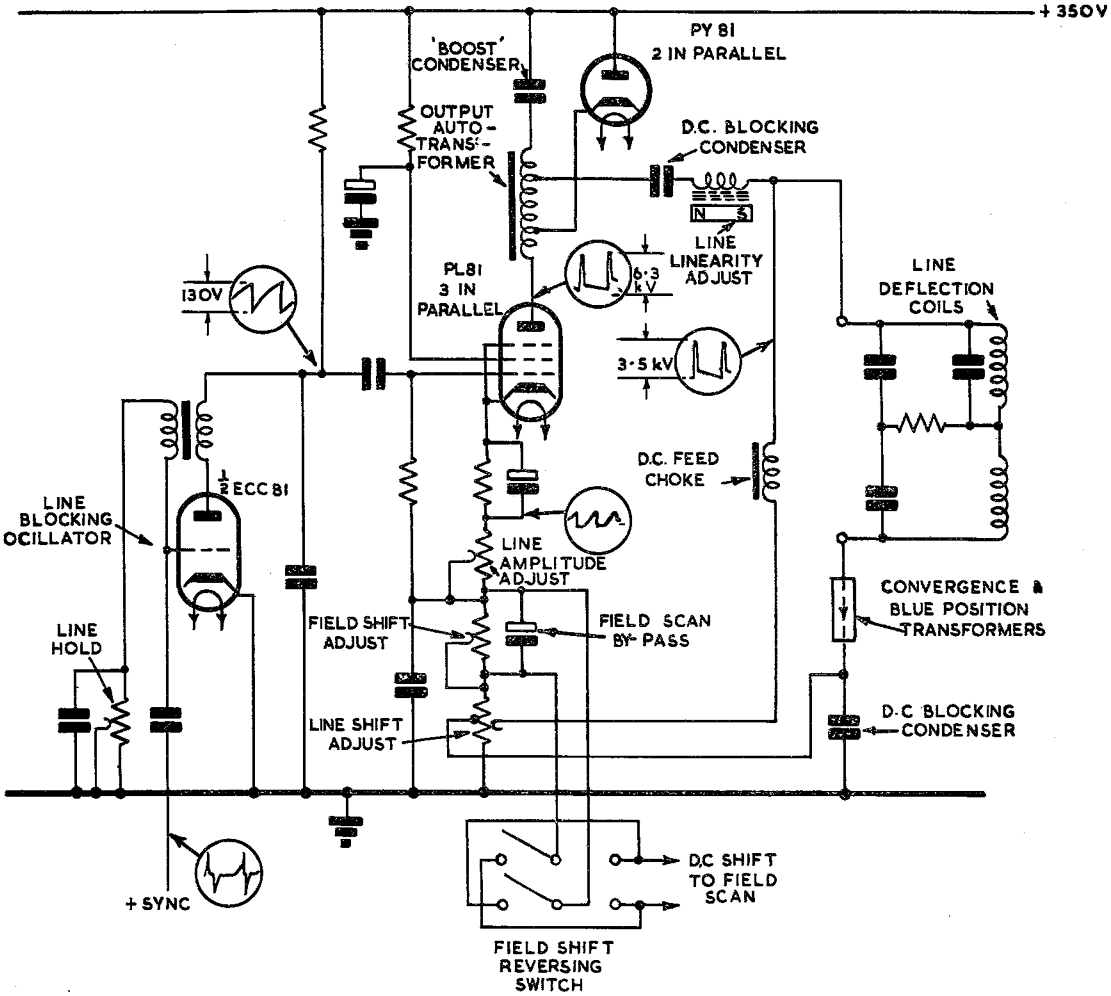

Fig. 10 - Line scan generator

4.2. Line Time Base

An energy-recovery type line scan generator is used to provide the peak-to-peak scanning current of 2 amperes into deflector coils of inductance 11·8 mH. This corresponds to an input per cycle (without energy recovery) of 24 millijoules, compared with 9 millijoules required by the normal 21 in. wide-scanning-angle monochrome receiver tube.

The line time base circuit is shown in Fig. 10. A blocking oscillator saw-tooth generator is used to drive the output stage, which consists of three PL81 pentodes with two PY81 efficiency diodes, and the R.C.A. line deflection coils are parallel-fed from the output auto-transformer. Cathode current of the output stage is used to provide adjustable vertical and horizontal raster shift of either polarity. The line deflection coils are a.c. coupled to the driving circuit (by blocking condensers) and a choke provides the d.c. connection to the slider of a potentiometer in the cathode circuit. The inductance of this choke is approximately ten times that of the scanning coils so that a loss of only ten per cent of useful scan current is

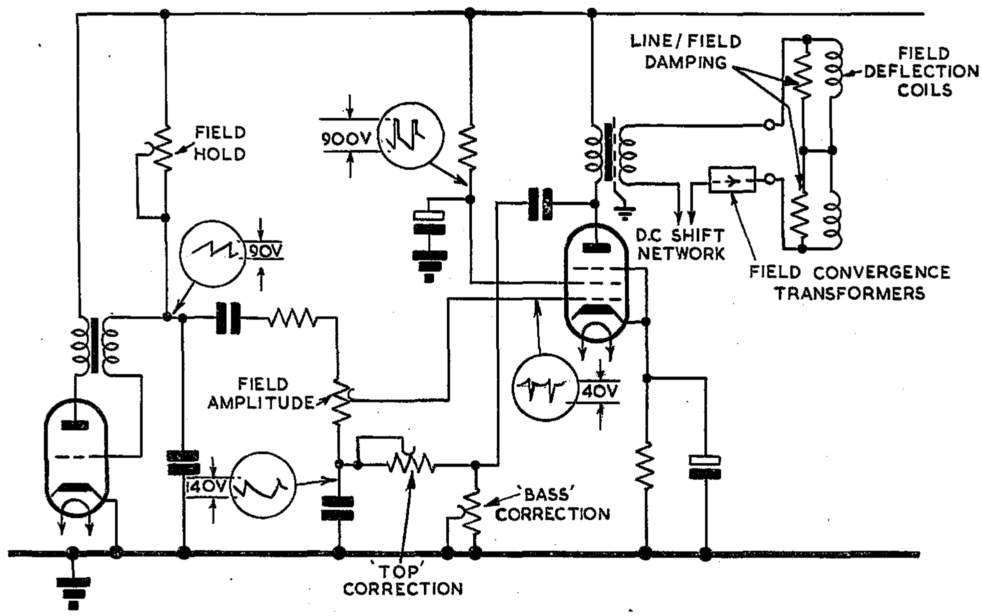

Fig. 11 - Field scan generator

incurred; but it must be designed to have a low d.c. resistance and also to withstand a high voltage (3·5 kV) which appears across its terminals during the flyback period.

The design of the R.C.A. deflection assembly is such that it is necessary to maintain an accurate electrostatic balance between line and field windings, and the balancing networks connected across the deflection coils must be adjusted with great precision. If this is not achieved, cross-coupling gives rise to severe geometric distortion of the raster, usually appearing as an oscillatory velocity modulation of the early part of each line scan, with corresponding deviations in the vertical direction.

4.3. Field Time Base

The field scanning generator is of conventional design and is shown in Fig. 11. The blocking oscillator sawtooth generator drives a single PL82 type field scan output valve, and a mode of operation lying between "zero initial slope" and "minimum mean anode current"[1] is chosen to improve efficiency and to facilitate design of the output transformer. Feedback is via two adjustable time constants, the purpose of which is to provide compensation at high and low frequencies. The peak-to-peak scanning current is 0·4 amperes into coils having a series resistance of 56·5 Ω with inductance of 128 mH, and each field deflection coil has a 1 kΩ resistor in shunt to assist in the reduction of the effect of line-to-field coupling already mentioned.

4.4. Convergence Circuits

To a first approximation the current waveforms required in the magnetic convergence coils are parabolae of line and field frequencies. In addition, a sawtooth component of either polarity is usually required. Ingenious circuits have been described[2] to provide approximations to the correct waveform in an economic

manner, and use is made of the inductance of the coils themselves to perform the integrating operation on the applied voltage. Although these circuits are adequate for the average domestic receiver, it was felt that, for a laboratory monitor, additional cost and complexity were justified in order to obtain the best possible registration of the three images, so that residual errors would then be due only to tolerances in the construction of the tube and scanning coils. The principle observed in the design of the convergence circuits for this monitor was to generate the required waveform from samples of the actual scanning coil currents, and then to use each circuit element for only one purpose. This resulted in convergence waveforms which have more precise shapes and are at all times functions of the true positions of the electron beams and, therefore, include minor non-linearities and changes in scan amplitude. This method of generating the convergence waveform raises three distinct circuit requirements.

a. Accurate sampling of the scanning waveform.

b. Individual control of amplification.

c. The provision of convergence coils capable of producing a magnetic flux which is a precise replica of the output valve current. (This entailed rewinding the convergence coils, as supplied by the manufacturer, to raise their resonant frequency).

Means for sampling the scanning current waveform are provided by the introduction of a low impedance in series with the scanning coils. This impedance takes the form of the primary of a transformer whose secondary is loaded by a capacitor or resistor according to the waveform to be generated. Three identical groups of line parabola, field parabola, line sawtooth and field sawtooth waveforms are all generated in this manner. The various waveforms are then combined in their correct proportions by variable resistance networks and the sum of each group is applied to the grid of an output valve which drives one convergence coil. Fig. 12 shows the arrangement of one such circuit. It will be noted that each convergence coil is bifilar and is connected in series opposition so that the magnetic flux due to the d.c. component of the anode current may be cancelled in the convergence field. For convenience in setting up, a controlled degree of unbalance in the current flowing in the two windings may be introduced to assist or oppose the effect of the permanent magnet which is part of the convergence coil assembly.

4.5. Blue-Positioning Circuit

During the development of this monitor it was found that although convergence could be correctly set up in the centre of the screen, on many tubes there existed a horizontal displacement of the blue raster, which could not be corrected by adjustment of the blue-positioning magnet. This displacement varied along the line and it therefore seemed desirable to provide a dynamic "blue-positioning" magnetic flux which could be coupled to that produced by the permanent magnet. This was achieved by adding a pair of small coils to the yoke of the blue-positioning unit and passing through them a line sawtooth current, adjustable in amplitude, shape and polarity. This waveform is obtained in the same way as the convergence waveform, and its shape is then controlled by a network having adjustable low-frequency loss or gain. The amplitude of the sawtooth is variable through zero to give either polarity, and is

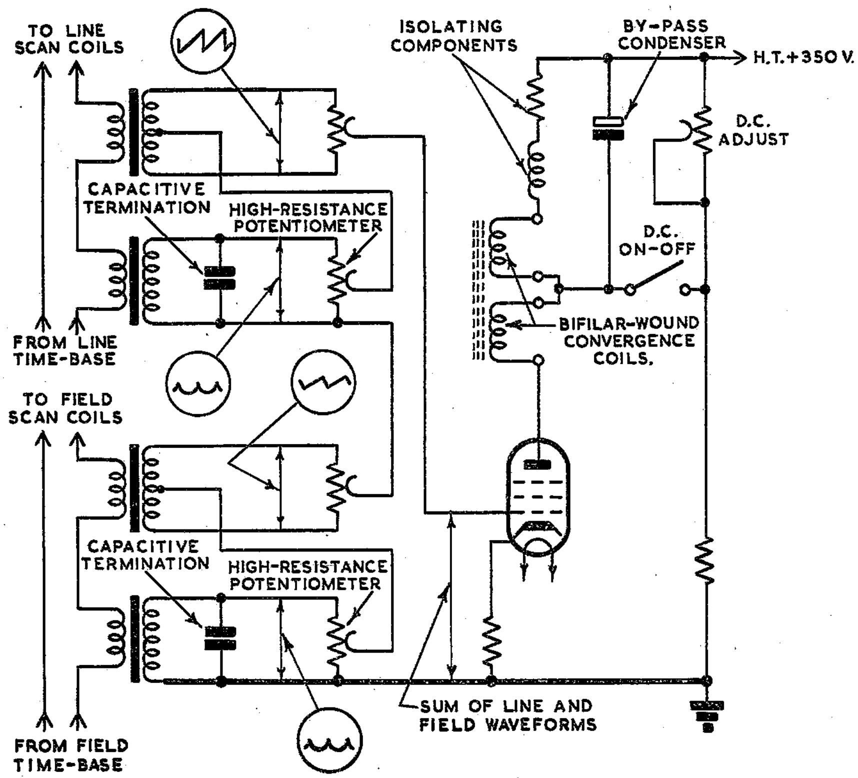

Fig. 12 - Convergence circuit

then applied to the grid of a pentode whose anode is connected to the blue-positioning coils. The d.c. component of the anode current is arranged to assist the action of the permanent magnet and it is not necessary to cancel its magnetic effect.

4.6. Video Amplifiers

The cathode-ray tube is driven by a triple video amplifier of bandwidth exceeding that of the signal which it is required to handle. The maximum undistorted output voltage is approximately 120 V peak-to-peak, and the inputs of the amplifiers are provided with switching facilities to accept one of two alternative inputs:

1. R, G, B colour-separation signals at standard level.

2. The output of a decoder having a composite N.T.S.C. video waveform as its input.

Where the 21 in. Tricolor Kinescope is used in a commercial receiver, colour balance is often achieved by variations of the three "G_2" potentials. In this monitor it was felt that colour balance adjustment would be simpler if changes in video gain could be made without change of background brightness, and that improved short-term stability of background colour balance might be obtained by connecting all three G_2 electrodes together. The video amplifiers are therefore fitted with input potentiometers to provide colour balance control, while the main gain control is a three-

gang 75 Ω potentiometer connected across the incoming feeds. In addition, a switch is fitted at the inputs to the three video amplifiers to combine the three signals so that adjustment of monitor colour balance may be made without access to a monochrome input signal.

It is, of course, important in high quality displays to preserve the d.c. component of the three colour-separation signals, and great care has been taken to ensure that the tube potentials corresponding with picture black level do not vary with picture content or h.t. voltage. To this end the d.c. component of the signal is reinserted by means of keyed clamps at the grids of the output valves, while the anodes of the output valves are connected to the cathode-ray tube grids by means of carefully adjusted d.c. coupling circuits. To prevent small variations in h.t. line voltage affecting the black level of the picture, the screen grids of the output valves are connected to the h.t. line via a neon stabiliser, and for the same reason the cathode followers which feed flyback suppression pulses and d.c. potential to the tube cathodes have a grid potential which is an adjustable fraction of h.t. line voltage. It has been found in practice that these measures together with a stabilised e.h.t. supply provide adequate freedom from drift.

4.7. Tube Protection Unit

The very high proportion of beam current which is collected by the shadow mask in this type of tube leads to a difficulty similar to that outlined in Section 2 in connection with the projection display. If the maximum average beam current recommended by the tube manufacturers is exceeded for any substantial period, a change of colour purity may be observed which seems to be due to temporary warping of the shadow mask by localised heating. It is, therefore, necessary to provide some limitation to the power which may be absorbed by the shadow mask, but in order to achieve adequate highlight brightness in small areas it is desirable that the e.h.t. supply should be capable of currents in excess of the safe average beam current. Some special device is, therefore, necessary. Because of the relatively low efficiency of the red phosphor it was assumed that the red gun would be most likely to carry the highest beam current during any excessive highlight, and therefore the unit uses the red video signal as a control.

The circuit arrangement is shown in Fig. 13. Whenever the red video signal rises above a pre-set reference voltage, the d.c. potential applied to G_2 of all three guns is progressively reduced, thereby preventing an excessive power input to the shadow mask. The time constant in the anode circuit of the control triode permits short pulses of high beam current to flow, but the limiting action comes progressively into operation if the duration of such peaks increases.

4.8. Power Supply

The total h.t. consumption of the apparatus when it is operating as a complete receiver with v.h.f./i.f. amplifiers and decoder amounts to 800 mA at 350 V and 600 mA at 275 V. It was, therefore, impracticable on grounds of space and heat to stabilise these two supplies, but sufficient smoothing capacity has been included in the power supply to prevent excessive ripple appearing on the h.t. line. At the same time the circuits handling video signals have been arranged to cancel load fluctuations as far as possible.

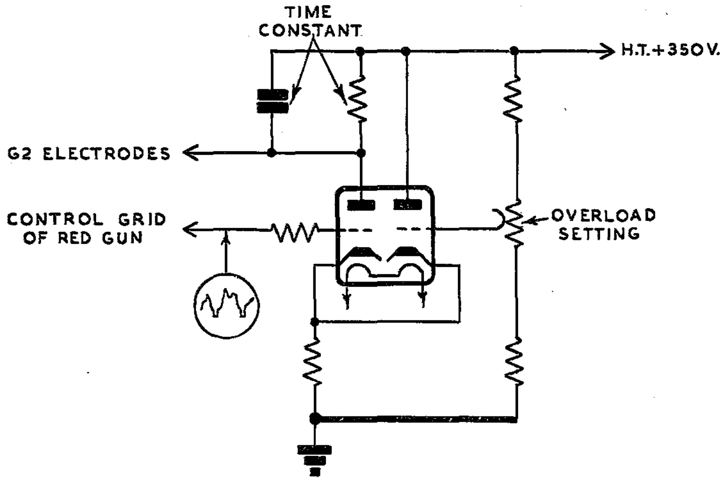

Fig. 13 - Tube protection circuit

The tube final-anode supply is obtained from an r.f. type of e.h.t. unit, the output being stabilised to better than 1% (no load/full load) by a negative-feedback system. The output voltage of the supply is adjustable between 24 kV and 26 kV and the unit will deliver a mean current of 1 mA and peaks of a few millisecs duration up to 2·5 mA. A "G_3" (focus) supply adjustable between 3 and 5 kV is included in the e.h.t. unit.

To facilitate switching on this monitor without damage to any part of the circuit, a thermal delay switch is included in the power supply to give a delay of between 1½ and 2 minutes between switching on the heaters and the h.t. supply. Since power for the e.h.t. unit is obtained from the h.t. line this delay switch ensures that no e.h.t. will be applied to the tube prematurely, and a further protection device on the time-base chassis prevents the application of power to the e.h.t. generator unless the scans are working.

4.9. Performance

This monitor has shown itself able to exploit the capabilities of the R.C.A. 21 in. shadow-mask tube satisfactorily. After a preliminary warm-up period, the stability of registration, colour balance and geometry is sufficient to permit its use for serious experimental work, and the performance of the monitor is, furthermore, maintained up to the maximum power input ratings of the tube.

5. ACKNOWLEDGEMENTS

The design of electronic circuits for the three monitors was due principally to E.R. Rout and S.M. Edwardson.

6. REFERENCES

1. Emms, Edward T., "The Theory and Design of Television Frame Output Stages", Electronic Engineering, March 1952.

2. Obert, M.J., "Deflection and Convergence of the 21 in. Colcr Kinescope", R.C.A. Review, March 1955.

EGF